The Occurrence of Gold in Ontario

(WITH DISCUSSION)

BY

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By J. B. Tyrrell, *Member*.

Up to the present time the Dominion of Canada has contributed 63,700,000*l*. to the world's gold supply, and of this total the great placer or alluvial camps of Klondike in the Yukon territory, and Cariboo, etc., in British Columbia, have contributed respectively 30,000,000*l*. and 14,400,000*l*., leaving 19,300,000*l*. as the contribution of both the placer and quartz mining camps of the rest of the Dominion. Of this latter amount the quartz or vein mines of Ontario have contributed, to December 31, 1912, 900,000*l*., all of which came from localities in the latter province underlain by rocks of Pre-Cambrian age.

The question at once arises why, if Ontario is rich in gold-bearing lodes or veins, these have not been discovered or developed as they have been in other countries where similar rocks prevail.

The answer to this question is involved in a knowledge of the history of the country from the Pliocene period down to the present.

Pre-Cambrian rocks, similar to those of Northern Ontario, are known in many other parts of the world, and among them may be mentioned Minas Geraes in Brazil, Kalgoorlie in Western Australia, Rhodesia and India. In all these places gold-bearing lodes have been worked extensively, and have yielded enormous returns to those who have been fortunate enough to own them.

But in these countries, as well as in that far north-western portion of our own country, the Klondike, rock decomposition went on continuously throughout all later geological periods. Rain descended on the loose decomposed rock, dissolved parts of it, and carried the insoluble portions down into the streams, and these streams in their turn carried the lighter portions down into the sea, while the streams themselves concentrated the gold and other heavy minerals contained in the decomposed rock into the more protected parts of their channels, forming placer deposits. Compared with gold-bearing quartz veins or lodes in undecomposed rock these placers are readily discovered, and when discovered, yield up their riches

quickly and easily to the miner. In addition to which, 5 dwt. of gold to the ton of gravel constitutes a rich placer in almost any country, while a similar quantity of gold, in quartz, is impossible to extract at a profit except under the most favourable conditions. Placers, when discovered, cause a rush or stampede of prospectors and miners into the country: these men quickly scatter about and greatly extend the knowledge gained by the original discoverers.

With the confidence engendered by abundance of gold at various places in these placer deposits, and with the necessary experience and capital supplied directly or indirectly from the same sources, search is then instituted for quartz veins or lode deposits, often successfully, so that great quartz veins have been opened up in the same countries, and in others in the vicinity of them. But for the placer mines of Brazil, California, Colorado, Australia, etc., it is doubtful whether the rich gold quartz veins of these countries would have even yet been discovered or developed.

In Ontario gold-bearing quartz veins occur in many places, and in the very long period which intervened between that time in some of the later Palæozoic Epochs when the Pre-Cambrian rocks were raised above the Palæozoic seas, and the close of the Pliocene, rock decomposition on a tremendous scale undoubtedly took place, for during all this immeasurably vast interval of time these rocks were above the level of the ocean, and were constantly subjected to the corroding influence of atmospheric and meteoric agencies. This decomposed rock was then carried away by streams which assorted the undissolved portions and left the heavy gold in the valleys, while they carried much of the lighter material down into the sea.

In this way alluvial deposits, rich in gold, were undoubtedly formed in many parts of Ontario, where they must have existed during the Pliocene and earlier periods. The rich alluvial gold-fields of the Klondike, where, in an area underlaid by Pre-Cambrian rocks, sedimentation has been continuous from Miocene times down to the present, give us some indication of what must have been the extent and character of those alluvial deposits in Pliocene times.

But in the Province of Ontario, and in those portions of Canada to the west and north-west of it, rock decomposition, and concentration through the agency of running water, have not been continuous down to the present, but on the contrary these processes were suddenly interrupted in Post-Pliocene times by the invasion of vast fields of ice, which moved with irresistible force over the country, and swept all the disintegrated rock, gravel, sand and other loose material along with it, even planed off and carried away

some of the underlying hard undecomposed rock itself. All this rotten and broken rock material was kneaded together by the flowing and crushing of the ice, which at the same time moved it southward, and deposited much of it over the southern parts of Ontario, and adjoining portions of the United States.

In this way the gold-bearing alluvial deposits which undoubtedly existed in many parts of Ontario during the Pliocene Epoch were removed and destroyed by glacial agencies.

Since the close of the Glacial Period, when the last of the ice invasions took place, there has not been a sufficient lapse of time to allow for any extensive decomposition of the hard Pre-Cambrian rocks, or of the included gold-bearing lodes when such are present. Consequently the present streams have been unable to form any important gold placers on account of a lack of supply of proper gold-bearing material from which the metal could be concentrated.

The few low-grade placers which are known to exist in the province have undoubtedly been derived from a re-concentration of glacial débris containing a little gold, and not from a concentration of material worn directly from the rock itself.

In consequence therefore of the erosive action of the ice during the Glacial Period, and of the comparative recency of that Period, there are no rich and extensive gold-bearing placer deposits in Ontario such as are found in most other gold-producing countries.

As these gravel or placer deposits have in most cases contained the gold first discovered in other countries, and as this gold was quickly and easily extracted from them, they were the means of drawing together the first great throngs of prospectors, and their absence from the Province of Ontario, and the consequent lack of this powerful attractive agent, has militated strongly against the discovery and development of its gold resources.

Gold was discovered in Ontario in the summer of 1866, in a quartz ledge on the property of Mr. J. Richardson in the Township of Madoc, north of Lake Ontario, but so little was known about gold by the men living in the vicinity who discovered it, that the identity of the metal was not determined until it was seen by H. G. Vennor, then in the employ of the Geological Survey of Canada, who immediately recognized it.

Five years later, in 1871, gold was discovered in quartz veins in the country west of Lake Superior, and from that time onwards up to the present it has been found in many places, but until recently very few, if any, of these discoveries resulted in the opening up of productive and profitable mines.

Such mines have now unquestionably been found in the Porcupine

District. The characters and conditions of occurrence of these payable gold-bearing veins are much the same as many, if not all, of those which had previously been exploited in other parts of the province. The occurrence of an ounce of gold more or less in a ton of vein matter can scarcely be regarded as of sufficient importance from a geological point of view to place these richer veins in a class by themselves, although the additional ounce may make a vast difference in their commercial value, and in the interest which may be attached to them in the promotion of the general welfare of the community.

In all places where gold has been found it has occurred more or less closely associated with quartz veins in Pre-Cambrian rocks, usually near the contact of acid intrusions with some basic rocks of either igneous or sedimentary origin.

The Porcupine District mentioned above has several profitable gold mines producing gold from veins of great regularity and continuity. Another district in which gold-bearing veins of very similar character also occur is situated in the vicinity of Swastika Station, on the T. & N. O. Railway. As the rocks with which the veins are here associated are proving to be sufficiently widespread to include many other areas both in Ontario and Quebec where gold is known to occur, and as the conditions of occurrence of these rocks are rather clearly defined at Swastika and in its vicinity, a brief description of this district will be of interest.

Swastika District.

The Swastika district* is fairly typical of the Archæan peneplane of Northern Canada.

Its surface configuration is characterized by low rounded hills and shallow valleys in which lie beautiful clear lakes with very irregular outline, connected by smaller or larger streams.

The country has all been severely glaciated from a northerly direction, and the rocks which underlie it have been planed down until all the weathered and softer portions have been removed, and that which remains is the hard rock, unaltered by surface or atmospheric agencies.

These rocks, however, are not now generally exposed over large

* See also a report on 'The Swastika Gold Area,' by E. L. Bruce, in the *21st Annual Report of the Bureau of Mines* (for Ontario), 1912, pp. 256-265, with map.

NOTE.—In the examination and determination of a large number of microscopical sections of the rocks of the district, I was assisted by Prof. T. L. Walker and Mr. G. S. Scott.

tracts, but are usually covered with a coating of clay or sand of Glacial or Post-Glacial age, and these surface deposits support a dense forest of spruce and other timber which, with the overburden of soil, make the work of prospecting slow and difficult.

The rocks which underlie the country, and in, or in connection with, which the gold-bearing quartz veins occur, are as follows, arranged in increasing age from above downwards:

Glacial and Post-Glacial
  Till, sand, clay and boulders.
Pre-Cambrian
  Diabase
  Minette and lamprophyre
  Albite diorite
  Felsite
  Conglomerate
  Diorite-porphyry
  Greenstone = highly altered diabase, amygdaloidal basalts, etc.

Greenstones.—Beginning with the oldest, the basement rock of the district is a fine-grained greenstone of Keewatin age, which in many places is hard and massive, while in other places it may be slatey or schistose. The more massive phases often exhibit the ellipsoidal or pillow structure so common in basic rocks of this age.

Examined in thin sections under the microscope the rock usually shows traces of ophitic structure, and appears to have been originally diabase, or similar igneous rock, which has been very highly altered, the alteration consisting in the formation of secondary hornblende and chlorite from former pyroxenes, and in the decomposition of the plagioclases with the formation of saussurite and the introduction of carbonates, the latter being probably derived, in part at least, from the decomposition of feldspar rich in lime. Quartz, usually showing strain shadows, is a secondary constituent in some of the rocks examined, while pyrites and magnetite are also both common secondary constituents, some of the smaller grains of magnetite having a surface covering of leucoxene.

This greenstone is remarkably similar throughout, both in horizontal and vertical extension, the alteration from its original character being just as far advanced 200 ft. below the surface as on the surface itself.

Diorite-porphyry.—Intruded into the greenstone is a batholitic mass of *diorite-* or *feldspar-porphyry*, which on the surface weathers to a dirty white colour, but on fresh exposure varies in colour from light green to red. It is usually distinguished by the presence of light-coloured phenocrysts of plagioclase, often altered to

saussurite, with occasional crystals of biotite, imbedded in a finer grained matrix of plagioclase, hornblende and chlorite. Quartz is also often present, and in some places to such an extent that the rock becomes a *quartz-mica-diorite*. In other places the ferromagnesian constituents may be absent and the rock then partakes of the character of *aplite*.

As a general rule the contact of the diorite-porphyry and the older greenstone is not a simple plane, but is rather a zone of varying width in which the rocks are mixed together in a very irregular manner. As originally formed, the contact was doubtless characterized by fragments of greenstone included in the porphyry, and probably also by tongues of porphyry extending into the greenstone. This original complexity has since been greatly accentuated by the squeezing and crushing to which both rocks have been subjected, accompanied by the formation of a number of small faults in and along which the rocks have moved in a very irregular manner.

With regard to the age of this diorite-porphyry, granites and granite-gneisses of Laurentian age, which are also younger than the Keewatin greenstones, occur a few miles to the south of Swastika, but I have not had the opportunity of observing any contact of the diorite-porphyry with these granites in this vicinity, if such occur, or of being able to determine the relative ages of the two rocks.

But in the Hurricana district of Northern Quebec, where gold-bearing veins occur in granodiorite-gneisses of undoubted Laurentian character, these rocks are cut by later diorite-porphyries, very similar to those of the Swastika district, and probably of the same age. It is not improbable, therefore, that the diorite-porphyries of the Swastika district are also of Post-Laurentian age.

Conglomerate and greywackes.—Overlying the greenstone and diorite-porphyry are conglomerates, greywackes, etc. They consist of a green fine-grained groundmass, the particles of which are in places rounded and waterworn, while in other places they are sharp, crystalline and angular, suggesting a volcanic or tufaceous origin. Some of the beds are fine-grained throughout, while others are packed with well-rounded, water-worn pebbles or boulders of the older rocks, such as greenstone, diorite-porphyry, red jaspilite, etc. In the finer varieties of these sediments it is often difficult to distinguish them from altered igneous rocks, but the presence of particles of jasper usually furnishes a distinguishing characteristic.

All have been deposited in water in a horizontal or approximately horizontal attitude, but since their deposition they have

been squeezed and upturned, so that the beds are often highly inclined. Many of the pebbles are shattered and broken, and in some cases the green matrix has been squeezed in between separated portions of pebbles of such distinctive rock as red jasper.

In many places the relative ages of the diorite-porphyry and conglomerate are difficult to determine with certainty, for, in the immediate vicinity of Swastika, the contact is obscured by superficial deposits, and near Kirkland Lake, a few miles further north-east, it is almost everywhere marked by a strong well-defined fault. However, in both places the conglomerate contains a plentiful supply of pebbles of the diorite-porphyry, and at one place near Kirkland Lake, on Claim No. 2566, the unfaulted contact was clearly seen. The pebbles are there rolled and well rounded, and, immediately above the contact, are composed entirely of diorite-porphyry packed together almost as closely as they can lie. This occurrence, together with the character of the pebbles in many other places, shows clearly that the conglomerate is later in age than the diorite-porphyry.

The greenstone, diorite-porphyry and conglomerate are the three most abundant rocks of the country, but, in addition, there are several varieties of igneous rocks which have been intruded into or through those above enumerated in the form of dykes or sills.

Felsite.—The oldest of these igneous rocks is a moderately fine-grained felsite, very similar in composition to the diorite-porphyry already described. Minute phenocrysts of plagioclase are crowded in a granitic groundmass of quartz and plagioclase, the quartz being occasionally almost entirely absent. Biotite, sometimes altered to chlorite, may be present, while pyrites, magnetite and leucoxene are secondary constituents.

It may occur in the form of rather indefinite dyke-like masses cutting the diorite-porphyry near the contact with the greenstone, in some cases seeming to be rather contact phases of the diorite-porphyry than independent intrusions. In other cases, it clearly occurs as dykes filling pre-existent fissures in the diorite-porphyry and in these cases the fissures may have been caused by contraction of the porphyry due to cooling, and the felsite may be merely a later phase or product of the same magma as that from which the diorite-porphyry was originally formed.

The zone of contact between the diorite-porphyry and the greenstone, in which these felsite dykes were seen to occur, is usually very much faulted, and while the fracturing and faulting began before the dykes were intruded, the movement along the fault-planes has

often continued after the dykes were formed, so that slicken-sided walls are comparatively common.

As far as my observation went, these felsite dykes are confined to the greenstone and diorite-porphyry, and do not cut the overlying conglomerates.

Albite-Diorite.—In the railway cutting a short distance west of Swastika Station on the T. & N. O. Railway, and in other places, dykes of coarse red albite-diorite, not very dissimilar in composition to the diorite-porphyry, cut through the conglomerate, and alter it to some extent near the contact. The abundant feldspars, which may compose 80 % of the rock, are albite-oligoclase, in which twinning and zonal banding are common. Biotite is bleached or completely altered. The groundmass is fairly coarse, and consists entirely of tabular plagioclase.

These dykes are of later age than those already mentioned, but they are particularly interesting as showing the persistence of the magma rich in alkaline feldspars.

Minette and Lamprophyre.—In addition to the above-mentioned highly feldspathic intrusions there are several others in which the ferro-magnesian constituents are much more largely represented. Among these is a coarse gabbro, showing a granitoid aggregate of diopside, biotite, greenish-brown hornblende, lime-soda feldspar, and accessory apatite and iron ore. It is very fresh, only the feldspars showing evidence of decomposition. A pale green diopside in stout idiomorphic prisms forms about half of the rock. On the steep face of the hill to the south-east of Otto Lake this rock is beautifully exposed for 15 ft. above the water as an intrusive sill, while lying above it is the fine-grained Keewatin greenstone with characteristic pillow structure.

In the railway cutting east of Swastika Station rock of very similar composition, but of different structure, has been intruded as dykes of minette through the greenstone. This minette is characterized by slender hornblende needles averaging one-eighth of an inch in length, and a few plates of chlorite. In a groundmass of orthoclase and plagioclase are crystals of hornblende, biotite (now chlorite) and diopside, while apatite is an abundant accessory. While the biotite has been altered, the other mineral constituents are quite fresh, in which particular it differs strongly from the older Keewatin rocks through which it cuts.

Dykes of very similar minette or 'lamprophyre' from a few inches up to many feet in width cut both the porphyry and conglomerate at the Tough-Oakes Mines, and on other mining claims in the vicinity of Kirkland Lake. They are approximately vertical, and

follow the general strike of the conglomerate, but they are all later in age than the conglomerate, for they have not participated in the folding to which the latter rock was subjected, and which had therefore assumed its present conditions and attitude before the minette was injected into and through it.

Some of the widest of these dykes are again cut by little narrow dykes, which stand out in relief on its weathered surface, and are much lighter in colour than the adjoining rock. They are found to consist chiefly of a soda or soda-lime feldspar, not dissimilar in composition to the dykes of albite-diorite.

A narrow dyke of bright green mica-lamprophyre, consisting of chlorite, orthoclase, some plagioclase, calcite and phenocrysts of biotite (now represented by chlorite) runs north-eastward across the claim of the Swastika Mining Company, cutting the greenstone and the diorite-porphyry. Whether it bears any relation to the other lamprophyres or basic intrusives of the district or not, I do not know.

Diabase.—A fairly fresh and moderately coarse diabase also occurs on the island in Otto Lake, and at some points on its shores. Whether it is in any way connected with the minettes just described or not, I was unable to determine. In any case, it is much newer than the Keewatin greenstone, and is not improbably of the same age as the Post-Huronian diabase of the Cobalt district.

Quartz Veins.—Quartz veins occur in the greenstone, diorite-porphyry and conglomerate or greywacke, and some veins have been also observed in the albite-diorite. Since, wherever gold occurs, it is more or less closely associated with these quartz veins, a knowledge of their character and mode of occurrence is highly important from an economic standpoint.

Most of the veins dip at a high angle, usually not more than a few degrees from vertical, though the dip may vary to some extent at different depths. Thus, at one place a vein may dip at an angle of 70°, while above or below it may be vertical, or even dip in the opposite direction.

In the greenstone and porphyry the veins are of quartz of a white or light blueish colour, often enclosing irregular masses of country rock. Very often the vein matter is distinctly banded, and in such cases the bands may be of green chloritic material, or they may contain a considerable percentage of dark tourmaline.

In the conglomerate the veins may contain a considerable proportion of specular iron ore, or, as in the case of the Tough-Oakes vein, they may contain a very large quantity of molybdenite. In almost every vein in which gold is found pyrites is more or less

freely disseminated through the quartz, and also through the country rock adjoining the vein. Some of the gold is intimately associated with this pyrites, while other portions of it are scattered through the quartz quite independently of the pyrites, so that in milling it is possible to catch from 50 to 80 % of it on amalgamated plates.

Faults.—In the tremendous disturbances to which these old rocks have been subjected, numerous slips have occurred, and faults have been formed of greater or less displacement. The fault planes may be simple or composite, and the slickensided surfaces show movement varying all the way from the vertical to the horizontal. Most of the faults are reverse.

In the northern portion of the Township of Teck the main fault zone runs roughly east and west parallel to the contact of the diorite-porphyry and conglomerate and to the strike of the folding which has affected the rocks in the Tough-Oakes and adjoining claims, and also to a rather prominent lamprophyre dyke which crosses the country near the above contact.

Farther south most of the faults observed are near the contact of the diorite-porphyry and greenstone, and are much more irregular in their direction and distribution, often crossing and intersecting each other at various angles. The main direction in any particular locality is probably determined by the direction of the line of the porphyry-greenstone contact. They appear to have begun to form shortly after the intrusion of the diorite-porphyry and to have continued to form until the close of the period of disturbance in which the lamprophyre dykes were injected into the adjoining rock.

The veins in this district, though not everywhere throughout the Pre-Cambrian rocks of Ontario, are usually associated with these fault planes, so that one or other or perhaps both of the walls may be smooth and well-defined. In one case a vein was seen to follow a fault plane for a certain distance to the intersection of another fault plane almost at right angles to it, when the vein turned sharply and followed the cross fault, the dark bands (of growth) in the vein turning sharply with the change in direction.

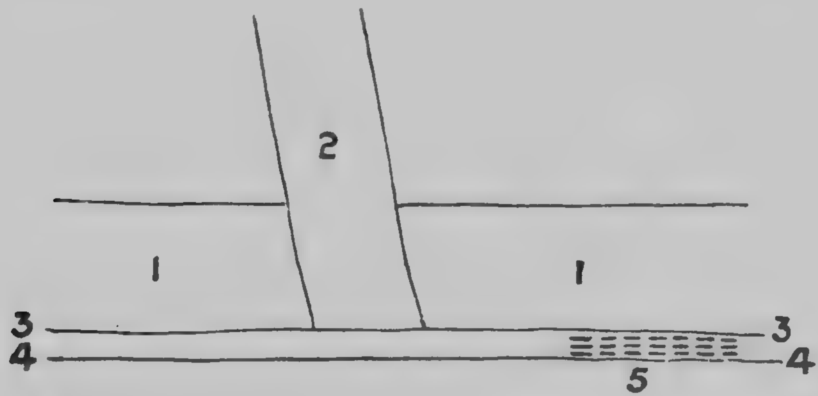
In other cases cross faults may pull or tear apart original fissures in which veins were being formed, permitting widening of the veins at and near the intersections, or the fissures may have been pulled back on one side of the cross fissures and not on the other, thus forming wedge-shaped enlargements of the veins on one side of the intersections.

Many of the quartz veins are at or near the contact of the diorite-porphyry and greenstone or conglomerate. The contact zone is not

usually very sharply defined, for the rocks were very much disturbed, crushed and faulted by dynamic agencies as they assumed their present condition after the intrusion of the feldspar porphyry. The veins may run parallel to the general trend of the contact, or they may branch off at angles from it along subsidiary fissures which have extended out into one rock or the other.

As stated above, the main veins usually approximate to a vertical attitude, while apophyses may branch off from them in all directions. Some of them are large, while others might be quite minute. Where such minute veinlets carry gold, they may convert a considerable extent of country rock adjoining the veins into payable ore.

In the norther portion of the Township of Teck, the gold is to a very large extent closely associated with molybdenite, which chiefly occurs along the walls of the veins, and is later in age than most of the quartz. Fig. 16 indicates clearly the character and relationship of the quartz, gold and molybdenite in one of these veins.



1. Quartz vein.
2. Quartz vein which has cut No. 1, but has been cut along the line 3.
3. Band of molybdenite on the fault plane, including gold 5.

FIG. 16.

In the porphyry-greenstone contact zone the fault fissures, when first formed, seem to have been usually accompanied by intrusions of felsite, which, as already stated, is composed of the same minerals as the diorite-porphyry; after which quartz was introduced, often in definitely banded form, and as this quartz was fractured by continued movement, gold and other minerals associated with it, including tellurium in some form, were also introduced. In some cases the

movement in the fault was continued until the quartz was broken down into an irregular fault-breccia.

Near the porphyry-conglomerate contact the veins run in very definite courses, and occupy fissures which cut indifferently across from one rock to the other.

The distinguishing feature of all these gold-bearing veins is their close association with intrusive masses of diorite or feldspar porphyry rich in soda or soda-lime feldspar. While these veins were not derived directly from this rock, for it had consolidated, had been fractured, quartz veins had been formed in it, and these again had been fractured, before the gold was introduced into them, it is probable that the later intrusions of felsite, albite-diorite and possibly also of lamprophyre were all phases of the same rock, were derived from the same original magma, and that the gold has also been exuded from this same magma.

In an undeveloped country, such as the northern parts of the Province of Ontario, in which gold mining is in its infancy, but in which it may be expected to have a much more extensive development, a knowledge of the way in which the gold occurs, and of the rocks with which it is associated, is of the first importance.

The Swastika district has been merely taken as a type to illustrate its occurrence in the Pre-Cambrian rocks of Northern Ontario. From the Hurricana country of Northern Quebec in the east, westward through Northern and Western Ontario, as far as Lake of the Woods, similar conditions appear to prevail, and it would seem not improbable that in the association of gold with certain definite types of rocks, the whole of this vast country may be one metallogenetic province similar in general character to that small portion of it here briefly described.

See also the following papers:—'The Goldfields of New Ontario,' by Walter Baelz. Translated by T. L. Walker. *Can. Min. Jl.*, May 1, 1912, pp. 299–304; 'Kirkland Lake Gold Deposits,' by R. E. Hore. *Ibid.*, July 15, 1913, pp. 424–31; 'Ore deposits of Kirkland Lake District,' by Chas. Spearman. *Ibid.*, October 1, 1913, pp. 599–601.

CONTRIBUTED REMARKS.

Dr. J. M. Bell: As a geologist who has travelled widely throughout the Canadian Hinterland both in Northern Ontario, and the region still farther North underlain by Pre-Cambrian rocks, Mr. Tyrrell is well qualified to address us on the subject with which his paper deals.

He has briefly mentioned several localities at which gold has been found in Ontario, and has given a more elaborate description of the rocks in the new gold field of Kirkland Lake, which he has taken as a type. While public attention is being riveted to some extent on this locality, it is interesting to learn of the various rocks of the district—greenstone schists, diorite porphyry, conglomerate, felsite, albite-diorite, minette, lamprophyre and diabase.

I do not agree with Mr. Tyrrell that the Kirkland Lake veins are typical of most of the Ontario veins. The gold deposits of this field consist generally of very narrow quartz veins, characterized by the mineral molybdenite and in places exhibiting specular showings of gold.

The country rocks are diorite-porphyry and a conglomerate in which occur brilliant pebbles of jasper. Though in places the country adjoining the narrow veins is highly silicified and gold-bearing, it is not characterized by much visible vein quartz. The veins of Kirkland Lake are on the whole well-defined, and the fissures appear to be persistent.

The gold veins of Porcupine are to my mind much more typical of others in Ontario than are those of Kirkland Lake. In that camp the deposits are of two more or less general types, (1st) the Dome type, consisting of large irregular lenses of white quartz, with, in places, wonderful showings of free gold, but of a generally low tenor, and (2nd) the Hollinger type, consisting of generally strong and fairly persistent quartz veins, with inclusions of schist. Gold occurs in both types in the quartz and in the schist. The walls of neither type are generally well-defined, and quartz stringers commonly ramify from the main vein into the country.

Deposits of quartz, very similar in character to those of Porcupine, occur at Swastika, Sturgeon Lake, Michipicotan, the Lake of the Woods, and in many other parts of the Ontario wilderness. They differ however, in one important respect. They have not yet been proved to be sufficiently rich to be profitable to work.

The Porcupine Field, as is well-known, was only discovered in 1909 and in 1911 was devastated by fire. It is highly creditable that in so short a time as the two years that have passed since then, so many mines in the camp should already have become productive. The monthly output of the Hollinger is about \$140,000, that of the Crown Porcupine about \$50,000, or \$60,000, and that of the Dome a somewhat greater amount than the latter.

Mr. Tyrrell has mentioned the difficulty of prospecting in Ontario, and has said that the great glaciers which in the past covered Ontario carried away the gold found prior to the invasion of the

country by ice, so that there is no wash to lead the prospector to locate gold-bearing veins. This is quite true, and in addition he has to cope with the difficulties of a very dense vegetation, and in many places a covering of moss. He soon learns to know that in a certain formation or formations in any locality he may expect to find quartz veins which he hopes to prove valuable, and may locate a likely area, but even here he may search indefinitely, and miss in his stripping a valuable deposit within a few feet, as there is no detrital gold, in the overburden, to give the scent.

Mr. Stephen J. Lett: The author informed me, in answer to my inquiries before the meeting, that the earlier writers had been mistaken about the identity of the 'graphitic material,' which they had said was such a marked feature of the deposits, there being no graphite present as a matter of fact, and what had hitherto been mistaken for graphite has proved to be molybdenite. I mention this for the benefit of those who did not hear question or answer, as the matter is of great interest. But this is not the only matter upon which the author and the earlier writers differ one from another, and as he did not criticize the papers and reports referred to in his footnotes, perhaps he will deal with a few points which have occurred to me in reading his paper and the papers, etc., in question.

Is it a fact that, as stated by one writer, the gold is commonly associated with 'much secondary quartz calcite and sericite,' and if so, from what is the sericite derived if the feldspars are soda-lime feldspars ?

Spearman writes 'the common variety of porphyry is a reddish alkali porphyry with predominating orthoclase phenocrysts' ; he also says that the acid porphyries are genetically associated with the deposits ; but another writer says that their favourable influence cannot be of a genetic nature, for they are much older than the deposits. Which is correct ?

Again, Walter Baelz states that the gold-bearing magma is directly connected with great granite intrusions, but the granites mentioned by the author are of Laurentian age, and the deposits are much younger ; besides, the author apparently does not associate the granites with the deposits, though the minerals mentioned by him as associated with the gold are such as are usually associated with acid magmas. On p. 151, when mentioning together the veins in the greenstone and porphyry, the author fails to take advantage of the favourable opportunity for referring to the influence of the 'country' on the gold contents. This being an important matter from an economic standpoint, it would be useful to have the author's

experience on this point, particularly as one writer has clearly stated that the greenstone is decidedly unfavourable.

It has been stated that the proportion of silver to gold has increased with depth; any information on this point cannot fail to be of interest.

I have received the following communication from Mr. A. G. Burrows, Assistant Provincial Geologist, Toronto. As the information embodied in the communication may be of interest to the members, I send it as a contribution to the discussion on Mr. J. B. Tyrrell's paper. Mr. Burrows writes:

'My attention has been called to the paper appearing in Bulletin 110 of the Institution of Mining and Metallurgy entitled 'The Occurrence of Gold in Ontario,' by J. B. Tyrrell, and also to the subsequent discussion of this paper by yourself and Dr. J. M. Bell.

I think that Dr. Bell is correct in stating that the occurrence of gold at Kirkland Lake is not typical of Ontario gold deposits.

The quartz veins in the best deposits so far discovered at Kirkland Lake are extremely narrow, usually only a few inches in width, but there is a considerable portion of replaced or impregnated wall rock along these veins which sometimes carries gold in economic quantities. There are other veins or lenses of quartz roughly parallel to a main vein, and also cross stringers of quartz which have allowed an extensive circulation in the adjacent wall rock. The ore deposit, consisting of quartz, calcite, country rock, etc., has been greatly disturbed and brecciated. A sample of ore has a dark grey appearance, and, unless wet, is sometimes difficult to distinguish from ordinary rock. This ore is quite different from most of the gold ore from other parts of the province, which consists so largely of white glistening quartz. The richness of the high-grade ore in gold and silver, as shown by shipments, and the presence of so much telluride (altaite) are noteworthy features.

For some time it was thought that the ore carried graphite, but Mr. C. A. Foster, of the Tough-Oakes mine, had the mineral, which usually occurs as a film on fracture planes, determined as molybdenite, which was confirmed by further tests at the Provincial Assay Office of Ontario. Graphite, if present, occurs only in minute quantity. Molybdenite has also been observed in ore from the Swastika area, a few miles to the south-west of the Kirkland Lake area.

As to the query: 'Is it a fact that, as stated by one writer, the gold is commonly associated with much secondary quartz, calcite and sericite, and if so from what is the sericite derived if the feldspars are soda-lime feldspars?' Original and secondary quartz in a vein can be distinguished with difficulty, particularly when a great portion of the quartz has been finely fractured. It is very likely that secondary quartz does exist in the veins. Secondary calcite is observed in all the thin sections examined. Sericite is present in some of the ore but only to a small extent. Sericite, like calcite, is found in almost all the altered rocks of northern Ontario and may apparently be a migratory mineral.

The prominent phenocryst of the porphyry is a plagioclase near the albite end of the series, but there is some replacement by $KAlSi_3O_8$ (orthoclase). Blades of sericite, sometimes in zonal arrangement, occur in the plagioclase phenocrysts.

An analysis of porphyry from the Teck-Hughes property gave—Silica, 66·48 %, Al_2O_3 15·42 %, Fe_2O_3 1·05 %, FeO 1·18 %, CaO 3·15 %, MgO 1·67 %, Na_2O 5·92 %, K_2O 2·56 %, H_2O 0·30 %, CO_2 2·65

The gold deposits of the Kirkland Lake area occur in sedimentary rocks of the Temiskaming series, and also in the reddish feldspar-porphyry which intrudes the older series. Veins have been found which cut both the sedimentary and igneous rocks. In the Swastika area the productive veins are in the greenstone near the contact with the feldspar-porphyry. The occurrence of these veins in the proximity of the contact of the older sedimentary or igneous rocks with an intrusive dyke rock (porphyry) is very suggestive of some genetic relationship between the veins and the intrusive rock.

The intrusion of the porphyry would shatter the older rocks along the contact, while the cooling, shrinkage and readjustment of the intrusive would result in the formation of the narrow fissures, later filled with quartz, which are so numerous in the porphyry itself. The vein filling could have ascended through channels in the porphyry, possibly being derived from the same source as a differentiation product. The term 'Laurentian' has been used during the past to include many rocks such as gneiss, granite, etc., the age relationships of which were not always known. The granite, syenite, etc., of the Swastika area were first grouped as Laurentian, but field work during the past year has proved some of these rocks later in age than the Temiskaming series and older than the Cobalt series. The gold-bearing veins occur in the Keewatin, Temiskaming, and a later intrusive (feldspar-porphyry) but not in the Cobalt series. The light-coloured intrusives are probably of the same age as the Lorrain granite in the Cobalt area, while the syenite, granite and feldspar porphyry may be facies of a plutonic rock underlying the whole area.

The distribution of the light-coloured intrusives is shown in the accompanying map.*

Mr. M. Brown Scott, Junr.: The confusion caused regarding the molybdenite in Kirkland Lake district was caused by the application of the term 'graphite' to that mineral by the prospectors and first entrants to the district, seemingly from lack of acquaintance with the characteristics of the former mineral. The writer, on obtaining a specimen, determined the nature of the mineral in question. The molybdenite is often closely associated with a very thin film of gold, and on the cleavage plane has what might be termed a slickenside appearance. Occasionally small crystals of altaite and tetradymite are found interspersed with pyrites, and in

* Map of Kirkland Lake and Swastika Gold Areas, accompanying Part ii, vol. 23, Report of Bureau of Mines, 1913. *See* also Bureau of Mines Report, vol. 21, containing report by A. G. Burrows on the Porcupine District.

close relation to the molybdenite, but although some specimens have shown native gold to be intermingled with these crystals, in no case could the presence of tellurides of gold or silver be shown. It must not be inferred that this precludes the possibility of such tellurides being present, but when taken in conjunction with the large amount of native gold present, it points conclusively to the fact that the phenomenal gold values do not exist as tellurides, as has been stated and suggested by several writers on this point.

AUTHOR'S REPLY TO DISCUSSION.

Mr. J. B. Tyrrell: Dr. J. M. Bell does not agree with me 'that the Kirkland Lake veins are typical of most of the Ontario veins,' but that 'the gold veins of Porcupine are . . . much more typical of others in Ontario than are those of Kirkland Lake.' He divides the Porcupine veins into two types, '(1st), the Dome type, consisting of large irregular lenses of white quartz,' and '(2nd), the Hollinger type, consisting of generally strong and fairly persistent quartz veins, with inclusions of schist.'

The Porcupine gold-bearing veins, though sub-divided by Dr. Bell into two classes, on what would appear to be physical characteristics, may, on a little consideration, be recognized as agreeing very closely with those described at Kirkland Lake. ! the Porcupine area, both at the Hollinger and at the Dome n the veins, though differing somewhat in shape, occur near contact of acid porphyritic igneous rocks and basic greenstones or conglomerates, the veins sometimes occurring in the porphyries themselves but much more often in the contiguous rocks. Both rocks are usually somewhat foliated and have evidently been subjected to considerable pressure or strain. It was doubtless the physical conditions which prevailed in those rocks at the time when the veins were formed, providing channels for the passage of the solutions bearing quartz, gold and other associated minerals, that controlled the general shape of these veins. For instance, the veins on the Hollinger are nearly vertical, and the rocks containing them appear to have been bent around a boss of basic greenstones which lies to the south of them. Their general appearance strongly suggests the saddle veins of Nova Scotia, with this difference, that in this case the saddle is lying on its side. The horizontal bending of the strata has probably given rise to larger ore channels at or near the apex of the bend than elsewhere, and may account for the greater richness of this property than those adjoining it.

The acid porphyry which is found associated with the gold in the Porcupine country has generally been spoken of as a squeezed quartz porphyry. That on the McIntyre property, south of Pearl Lake and east of the Hollinger mine, was found to contain large phenocrysts of orthoclase and plagioclase in about equal proportions, imbedded in a fine grained ground-mass of feldspar, quartz and sericite. A very few phenocrysts of quartz were also observed in it. The plagioclase is a soda-lime feldspar with a large preponderance of lime. In this particular instance the porphyry had been much crushed; but a little further west, on the opposite side of the Hollinger mine, it was found in some drill-holes in a less altered condition, consisting of a holocrystalline rock with large phenocrysts of feldspar in a coarse matrix of feldspar, chlorite and sericite. A few of the phenocrysts are orthoclase, but most of them are plagioclase in which the lime preponderates over the soda.

In the vicinity of the Dome, the porphyry examined has a much larger percentage of quartz, though some of the phenocrysts are of soda-lime feldspar.

Thus it will be seen that in their mode of occurrence, associated with porphyries rich in soda-lime feldspar, the gold-bearing veins of the Porcupine district fall in line with those described from Swastika and Kirkland Lake.

As stated in my paper, similar porphyries occur associated with the gold-bearing veins throughout the Pre-Cambrian areas of Canada. Among these Mr. A. L. Parsons has drawn attention to the fact that several of the gold-bearing veins on Lake of the Woods are definitely associated with dykes rich in plagioclase.

In answer to Mr. Lett's first question, whether it is true that the gold is commonly associated with 'much secondary quartz, calcite and sericite,' it is undoubtedly true that most of the primary quartz in the veins had been much fractured before the gold was introduced into it. In some places these quartz veins have numerous cross-veins of secondary quartz in them, but as far as I am aware this secondary quartz is not usually rich in gold.

Calcite is not a common constituent in the richer veins, though it is very common in the adjoining rocks, being probably derived in part from the decomposition of the plagioclase. Sericite is also often present near the walls of the veins, having probably been derived from the decomposition of some of the orthoclase present in the porphyry.

In regard to the character of the porphyry, I must take issue with Mr. Spearman's statement that orthoclase phenocrysts predominate. I have myself examined, or have had examined for me, a large

number of microscopic slides of this porphyry from a number of localities, and I find that, while orthoclase is usually present, and is sometimes abundant, plagioclase greatly predominates in this rock which I have designated 'diorite-porphyry,' and which Mr. Bruce in his official report published by the Bureau of Mines of the Province of Ontario, calls 'feldspar-porphyry.'

Since this paper was presented to the Institution, the Bureau of Mines of Ontario has also published a very valuable 'Map of the Kirkland Lake and Swastika Gold Areas,' by A. G. Burrows, with marginal notes. On this map Mr. Burrows also uses the term 'feldspar-porphyry' for these rocks. He regards them as later in age than the conglomerates (of the Temiskaming series), but the evidence which I presented in my paper shows clearly that they are earlier. I consider that, though the porphyries are older than the gold-bearing veins, the latter are genetically associated with them to this extent, that they have been derived from the same deep-seated magma.

With regard to Mr. Baelz's statement that the gold-bearing veins are connected with great granite intrusions of Laurentian age, I have no exact evidence as to the relative ages of the porphyry and the Laurentian granites, except that stated for the Hurricanaw district where Laurentian granites are intruded by porphyry similar to that at Kirkland Lake, and gold-bearing quartz veins are found in the granite adjoining the porphyry.

As to the influence of the country rock on the gold contents of the veins, I have but little evidence to offer. At the Hollinger property some of the richest veins are in an old greenstone, which is a highly altered diabase or basalt. In the Pearl Lake section of the Porcupine country the porphyry extends north-eastward as a tongue into the adjoining country, with basic greenstones, such as those above mentioned, on both sides of it, and the gold-bearing veins have an undoubted tendency to form in this greenstone. Some of the veins, however, are in the porphyry which is then often altered into a calc schist.

In many other places in the Pre-Cambrian areas of Northern Ontario quartz veins are scattered irregularly through the contact zone between porphyry and greenstone. In most of such cases they are short, and where gold is present in them it is also likely to be in short irregular shoots.

I would consider that the extent and value of the gold-bearing veins in the greenstone was much more fully controlled by the proximity and size of a mass of intrusive porphyry, and by the length and width of the fissures through which the gold-bearing

solutions were able to circulate, than by minute difference in the character of these old basic Pre-Cambrian rocks.

In the Porcupine district I believe that the percentage of silver as an alloy of gold is practically constant at any depths yet reached, but in the Kirkland Lake district, where tellurides of gold, silver and lead are present in appreciable quantities, the silver in the ore undoubtedly varies with the quantities of tellurides present. It is hardly likely, however, that the grade of the gold itself, and the quantity of silver which is alloyed with it, have suffered any change at any depth to which the shafts have yet reached in the Kirkland Lake district.

I can only repeat what I said in an earlier part of this paper, that my object in bringing the occurrence of gold in Ontario before members was to point out the association of gold-bearing veins in our Pre-Cambrian areas with diorite-porphyries, or intrusives rich in soda-lime feldspar.

Dr. Malcolm Maclaren, in a recent paper in the *Mining and Scientific Press*, has clearly pointed out a similar association in the Pre-Cambrian rocks of Kalgoorlie in Western Australia.

In summing up the value of a knowledge of the association of the gold-bearing veins in Western Australia with the intrusive dykes, Dr. Maclaren* says: 'It is not too much to say that had a geological map, showing all the porphyry and porphyrite dykes of the region, been available in 1893, every deposit now known, and some still unknown, would have been discovered within three months, and thousands of pounds' worth of useless work and misspent energy avoided.'

* 'Geology of the Kalgoorlie Goldfields,' by Malcolm Maclaren and J. Allan Thomson. *Min. and Sci. Press*, 9th August, 1913, p. 232.

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